Centre for Energy and Environmental Markets

UNSW
THE UNIVERSITY OF NEW SOUTH WALES
SYDNEY • AUSTRALIA



Microgrids and Hybrids in Remote Environments

Ted Spooner
Senior Lecturer UNSW

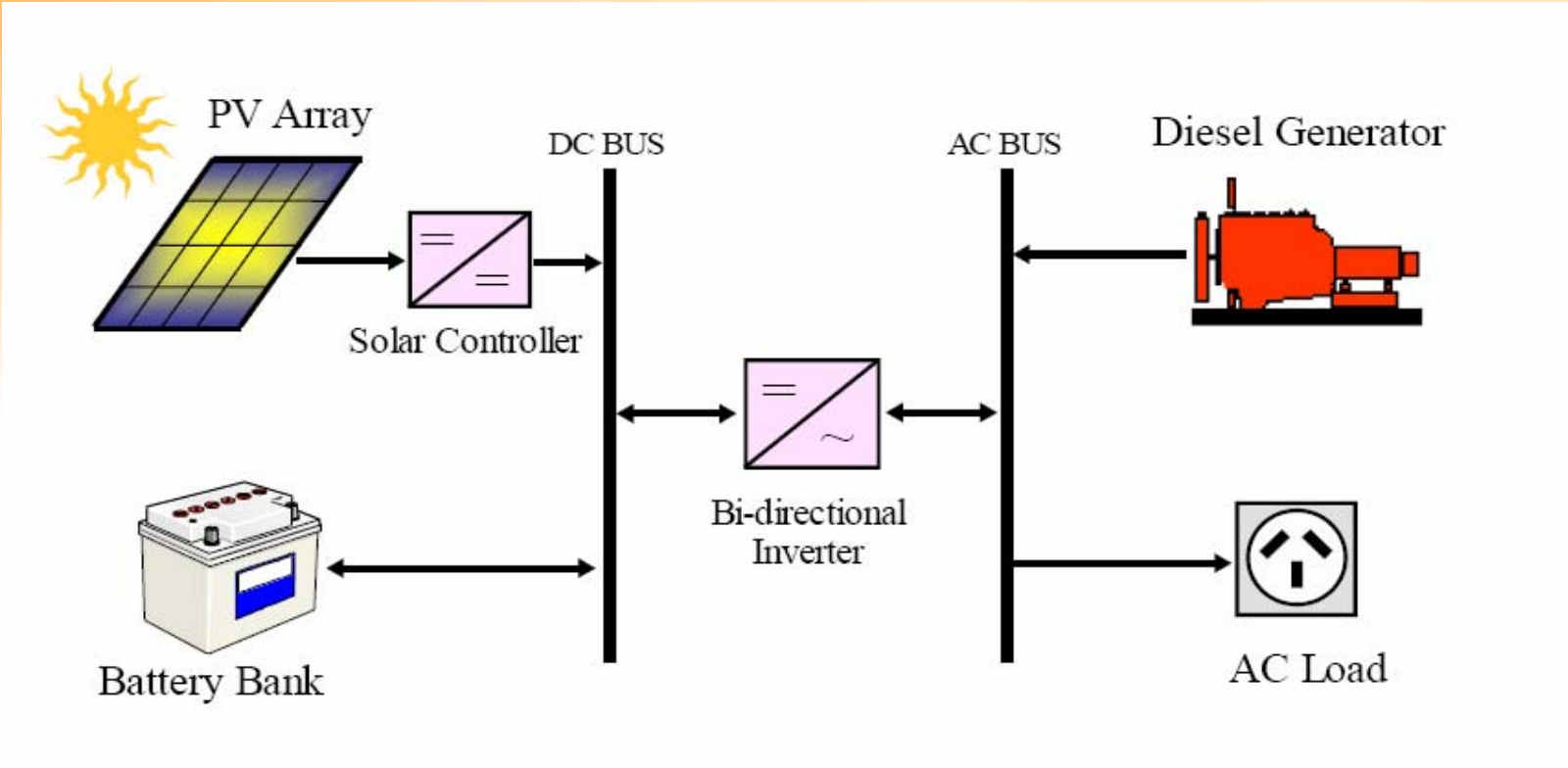
Outline

- Australian experience
  - Hybrid systems
  - Bushlight
  - Larger Systems
    - Kings Canyon PV.
    - Western Australia wind – diesel grids
  - Remote Systems in general
  - CSIRO research…Agent based control of DG

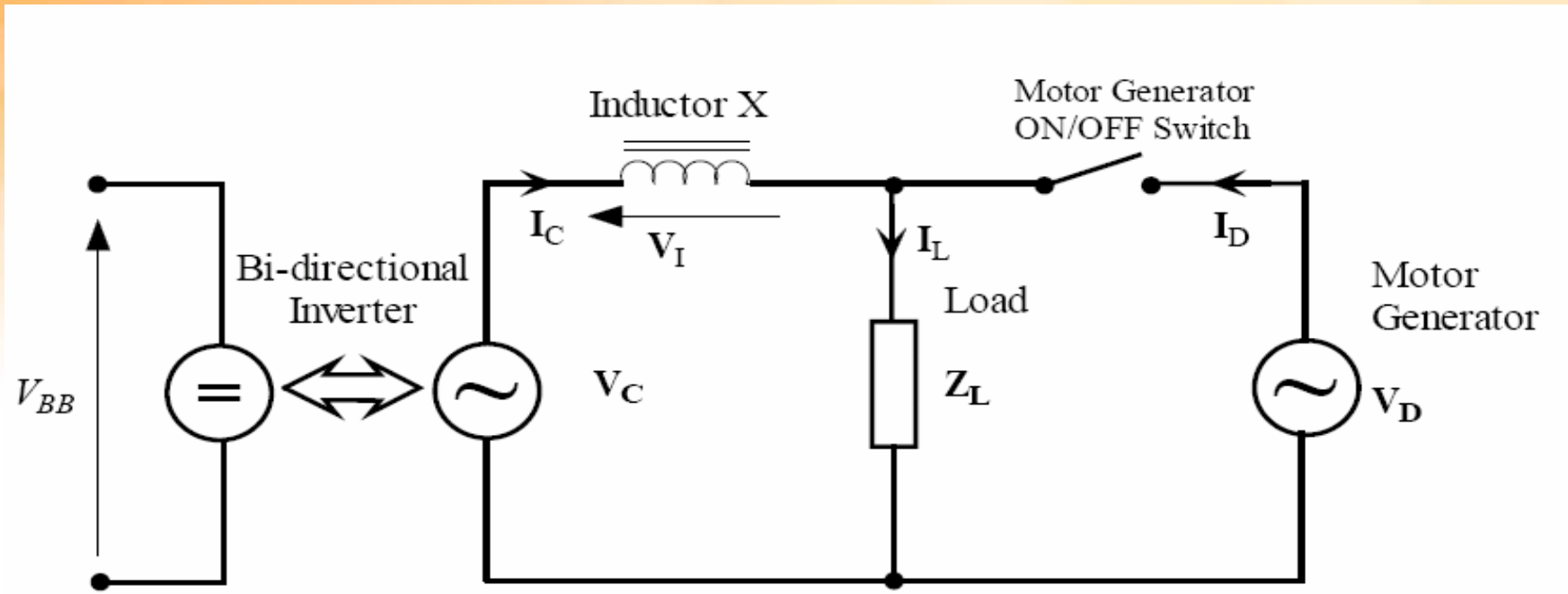
Australian Hybrids

- Large mix of systems.
- Range of locations from coastal to very remote.
- Newer/larger Systems
  - Interactive Inverter Systems operating in parallel with diesel gensets.

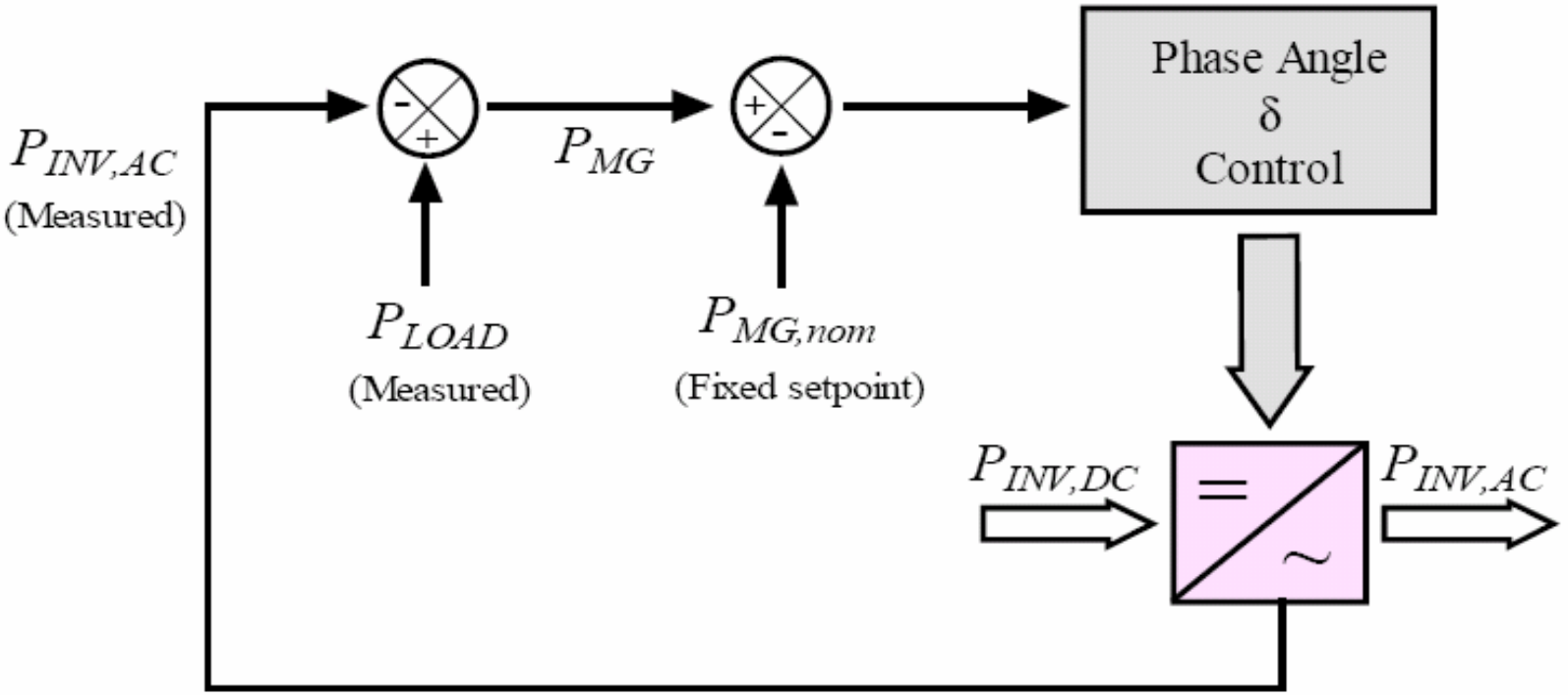
Typical Parallel configured system



Voltage source inverter



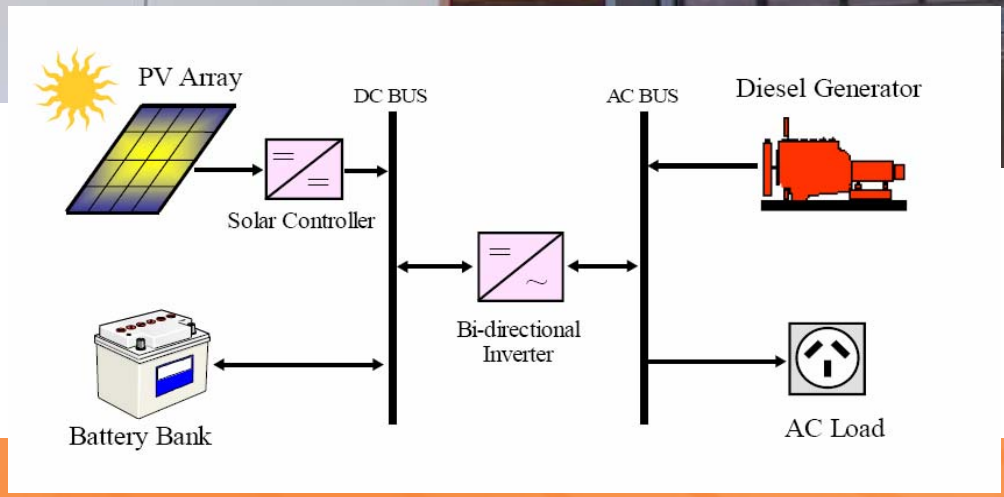
Simple local control



Bushlight

- Hybrid systems supplying Aboriginal Communities in Remote Australia.
- Single Hybrid system supplying a small community with multiple dwellings.

Bushlight
PO Box 8044,
Alice Springs 0871
AUSTRALIA
telephone: +61 8 8951 4344 fax: +61 8 8951 4333
Email: enquiries@bushlight.org.au
Web: http://www.bushlight.org.au

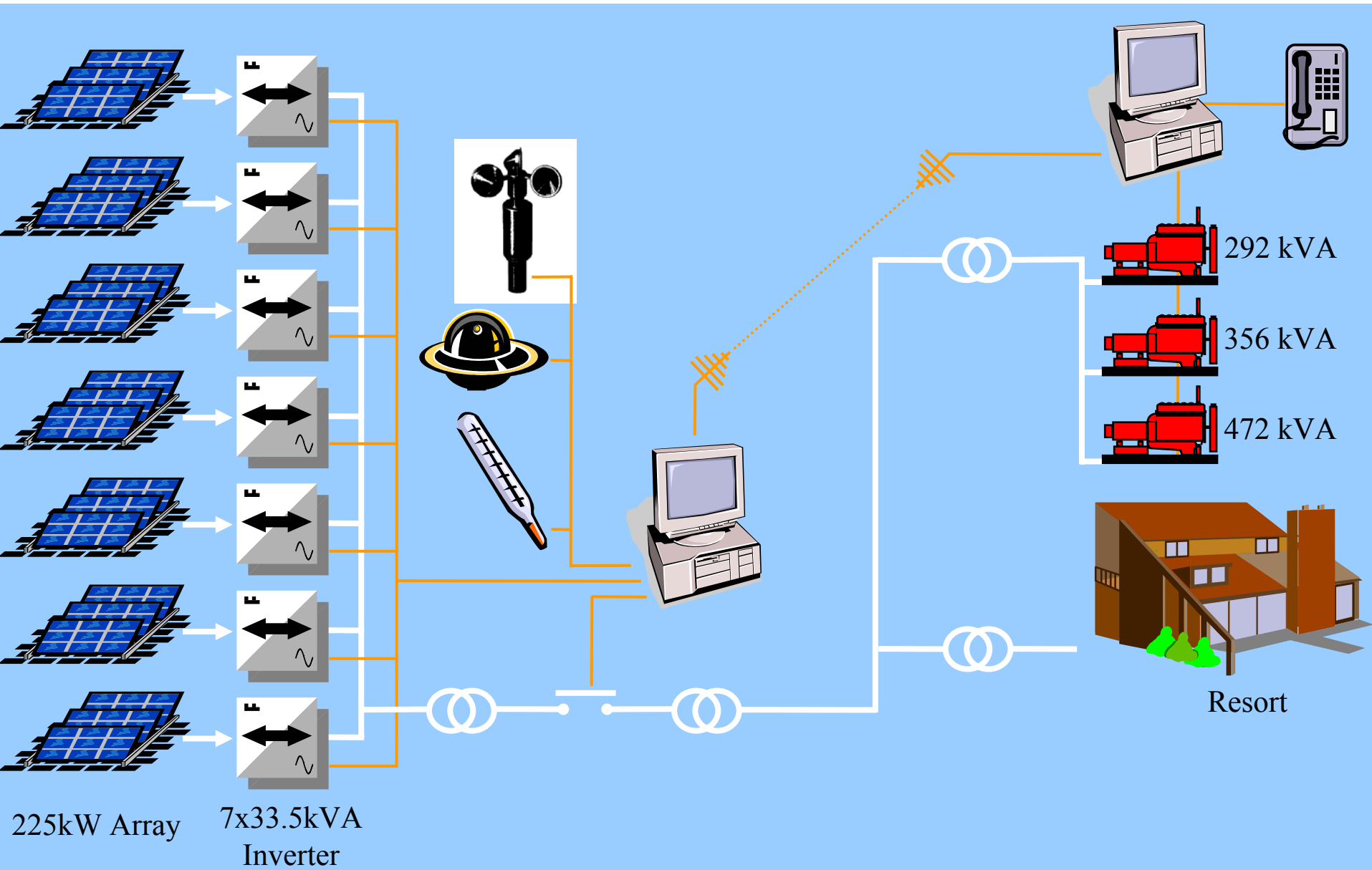

PV Array
DC BUS
AC BUS
Diesel Generator
Solar Controller
Bi-directional Inverter
Battery Bank
AC Load

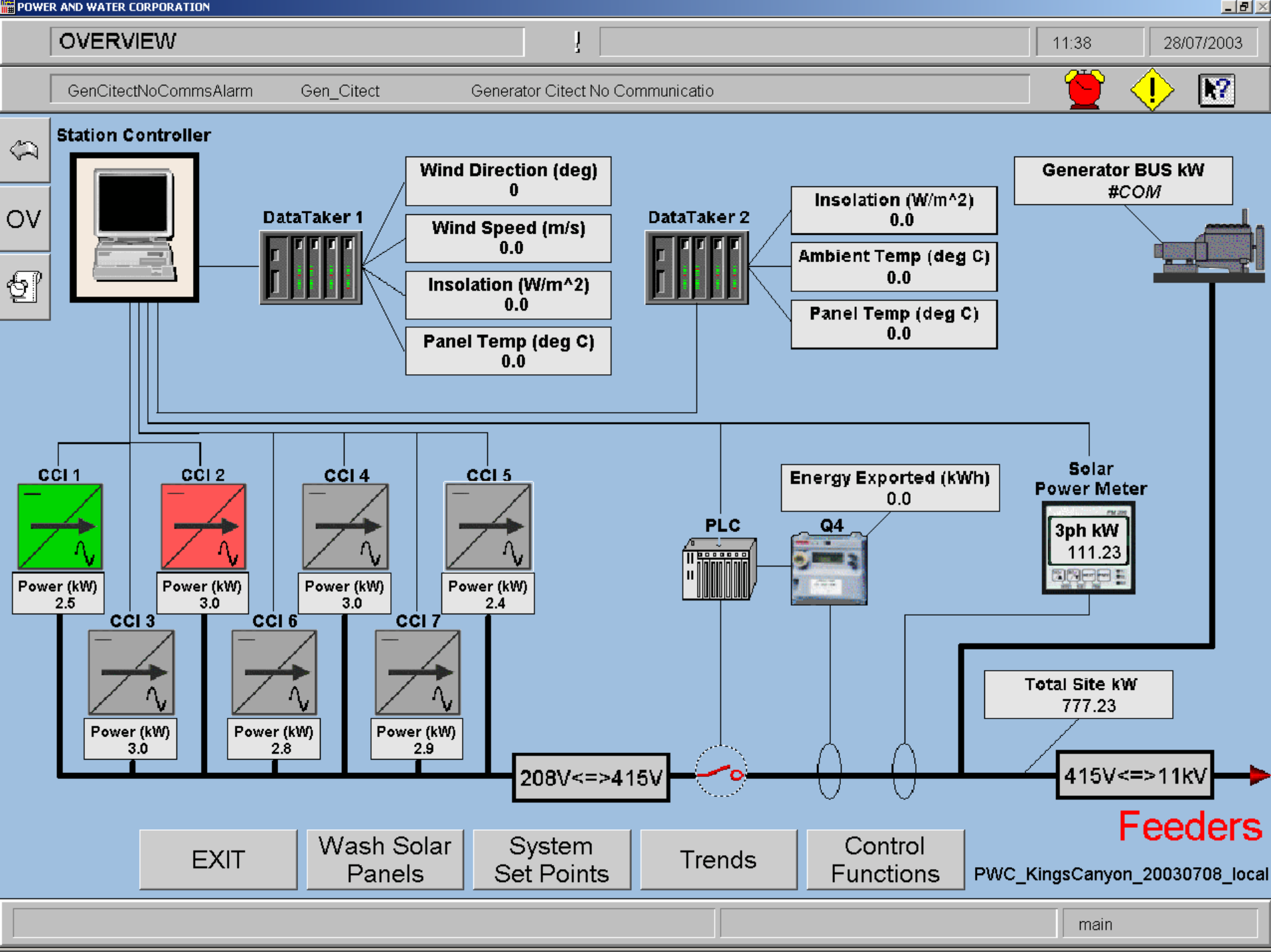
Larger Hybrid systems

- Can be more distributed
- Control systems use:
  - frequency/voltage droop characteristics
  - Communication systems for overall control & emergency situations.


Kings Canyon
225kW PV Array
7 x 33.5kW Inverters

Kings Canyon Schematic




POWER AND WATER CORPORATION
OVERVIEW
!
11:38
28/07/2003
GenCitectNoCommsAlarm
Gen_Citect
Generator Citect No Communicatio
OV
Station Controller
DataTaker 1
Wind Direction (deg)
0
Wind Speed (m/s)
0.0
Insolation (W/m^2)
0.0
Panel Temp (deg C)
0.0
DataTaker 2
Insolation (W/m^2)
0.0
Ambient Temp (deg C)
0.0
Panel Temp (deg C)
0.0
Generator BUS kW
#COM
CCI 1
Power (kW)
2.5
CCI 2
Power (kW)
3.0
CCI 4
Power (kW)
3.0
CCI 5
Power (kW)
2.4
CCI 3
Power (kW)
3.0
CCI 6
Power (kW)
2.8
CCI 7
Power (kW)
2.9
PLC
Energy Exported (kWh)
0.0
Q4
Solar
Power Meter
3ph kW
111.23
Total Site kW
777.23
208V<=>415V
415V<=>11kV
Feeders
EXIT
Wash Solar Panels
System Set Points
Trends
Control Functions
PWC_KingsCanyon_20030708_local
main

Wind Diesel Systems in Western Australia.

- **Denham**
- **Hopetown**
- **Bremmer Bay**

Hopetown Wind – Diesel System

Photos curtesy of D&WS
Diesel & Wind Systems (Perth)
www.daws.com.au

Hopetown

1. The two new Low Load Diesels installed at Hopetoun

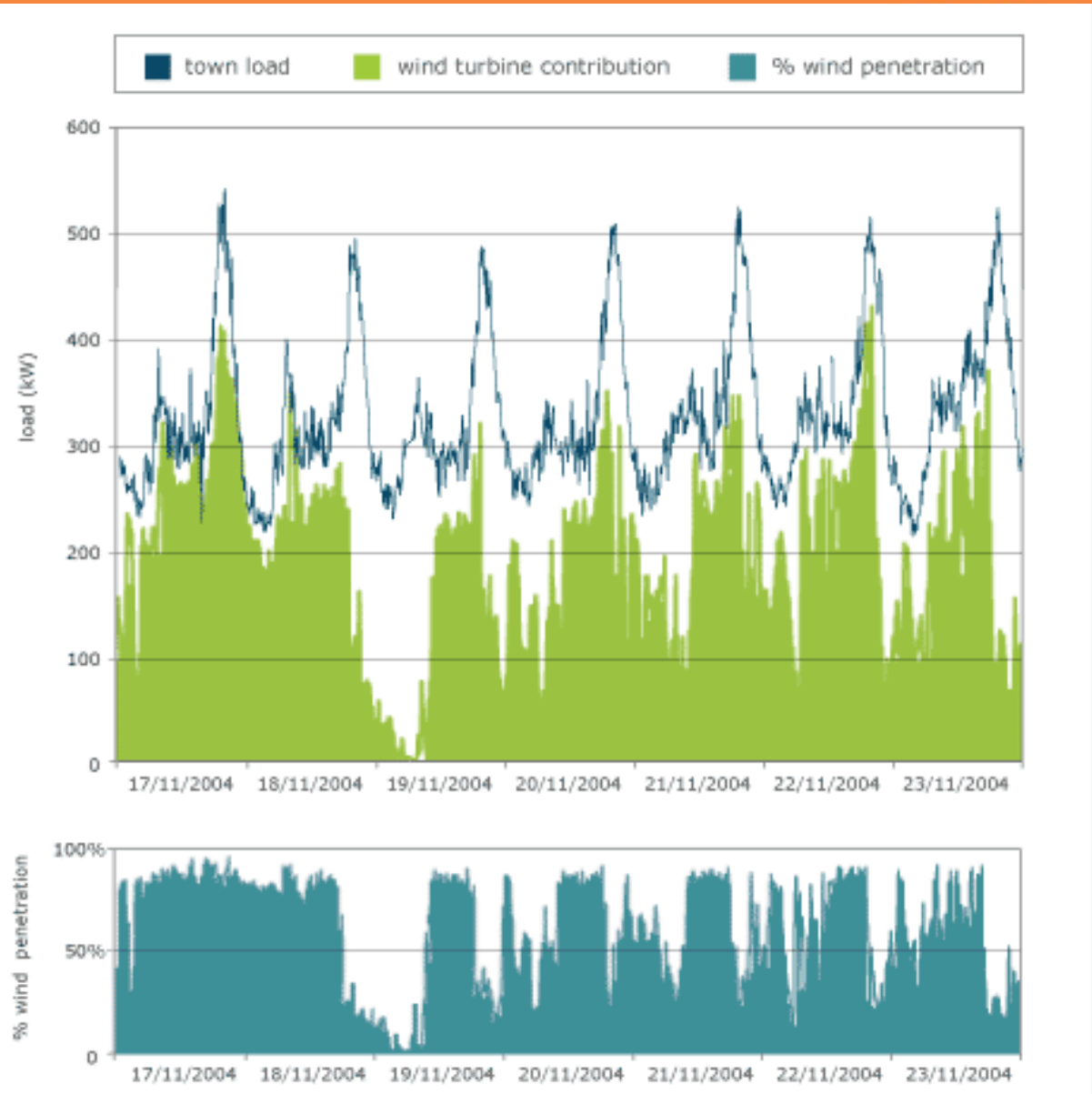
2. The windturbine at Hopetoun

Photos curtesy of D&WS Diesel & Wind Systems (Perth) www.daws.com.au

Hopetown

- 1 600kW Enercon E-40 wind turbine
  - Inverter connected turbine
  - 5km from diesel
- 2 320kW low load diesel generators
- Master system controller
- Two dynamic inverter controlled load dumps 16 sec rated.
- Fuel consumption without wind generator 980,000 litres/annum
- Fuel saving with wind generator expected to be 400,000 litres/annum

Hopetown - Wind Penetration



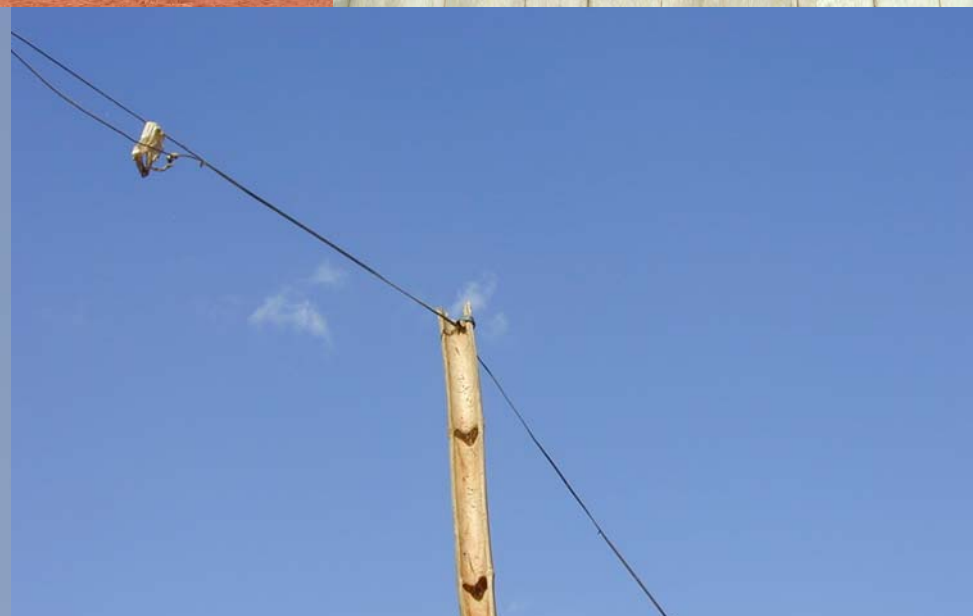
Graphs curtesy of D&WS Diesel & Wind Systems (Perth) www.daws.com.au

Remote systems are the hardest of all systems

- Long way away
- Harsh environment
- Difficult cultural issues
- Low funding
- Lack of education and training
- Need for quality systems
  - Reliability, Reliability, Reliability!

- IEC TC82…Standards on PV and Systems
  - IEC TC82-Joint working group JCWG
  - IEC 62257 Series "Recommendations for small renewable energy and hybrid systems for rural electrification"

MICROGRIDS - The Bad and the Ugly



Microgrids in Remote Locations.

- Minigrids or microgrids have considerable potential application in developing countries
  - Need right social context
  - Need all other factors in place (Education & Training)
  - Need to get small systems working reliably first.

Distributed Energy in CSIRO Australia

www.ict.csiro.au

- A realistic solution to large-scale deployment of DE resources in the distribution network
  - To impact the Australian network in 3 – 8 years time
- Adaptive, intelligent, distributed agents for various applications
  - Local end-use optimisation
  - Aggregation for network benefits
- A communications infrastructure
  - Communicating over the internet at least initially
- A new set of features in the Australian NEM
- Our assumption is that part of the growing supply-demand gap in Australia will be filled by Distributed Energy units
  - placed close to load centres
  - at connection levels where SCADA is not cost effective
  - and does not have enhanced functionality

CSIRO

One Framework, Many Applications

Application	Benefit
Demand-side management for a retailer's customers	Manage risk of exposure to wholesale prices
Island management for a distribution business	Defer capital expenditure on enhanced lines
Virtual generator harnessing geographical & technological diversity	Create a new business and encourage uptake of DG

The Agent Mindset

Agents run on local devices and measure, make decisions, and act in the real world

- Local control is good for:
  - Robustness
  - Scalability
  - Consumer acceptance
- Contrast with SCADA:
  - Prohibitively expensive to extend to consumer level
  - Top-down control is not scalable and sometimes not desirable
  - Opportunity: agents can be a last-mile solution

We're using PDAs for demo systems

Plus "tiny agents" (motes) to gather fine-grained data

Framework equally applicable to server-based applications

CSIRO

Key Technologies

- Coordinating a set of loads and generators to achieve both local and system goals
  - Local goals typically cost effectiveness
  - System goals involve aggregated response
  - Requires local modelling (by an agent) of capabilities and constraints of loads and generators
- Scalable and timely aggregation of distributed capacity across 10^4, 10^5, 10^6, … consumers
  - System response > 30 MW in order of minutes with communication delays in order of seconds
- BREAKTHROUGH WE AIM AT: demonstrating emergent behaviour to a desired outcome
  - Complex systems techniques: decentralised clustering, dynamic hierarchies, scale-free or small-world networks

What's Happening Now

- Writing an agent-based software framework
  - Joint project with Infotility (Boulder / San Francisco
  - Alpha release presently under test
  - Creating a uniform agent environment and a reliable platform across a diverse set of devices
- Developing multi-agent coordination algorithms
  - Focus: coordination in 04/05 and scalability in 05/06
- Demonstrating in hardware at Newcastle, Australia
  - Cooperating loads and generators in June/July
- Embarking on a trial with an industry partner
  - We won't do front-end deployment ourselves
- Looking for commercial partners in 05/06

DER Agent Demonstration in Newcastle

- Heating/cooling loads
  - Two cool rooms
  - One HVAC zone
- Distributed generation
  - Microturbine
  - Three photovoltaic arrays
  - Wind turbine
- Weather station
- Information sources
  - Market data
  - Weather forecasts

Thank you